FINAL REPORT

FEDERAL TECHNOLOGY TRANSFER ACT COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT AMONG THE SPRAY DRIFT TASK FORCE AND LABORATORIES OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY AND THE U.S. DEPARTMENT OF AGRICULTURE'S AGRICULTURAL RESEARCH SERVICE

Reporting Organization:
Agricultural Research Service
U. S. Department of Agriculture
Laboratories at
College Station, Texas
Stoneville, Mississippi
Wooster, Ohio

Type of Research Agreement:
Cooperative Research and Development Agreement

Research Agreement Number:
58-3K95-4-237

Research Agreement Award Date:
March 17, 1994

Reporting Period:
March 17, 1994 - March 16, 1999

USDA Cooperative Research and Development Agreement
No. 58-3K95-4-237

FINAL REPORT

To:

W. J. Phelps, Authorized Departmental Officer
Office of the Administrator, Agricultural Research Service
United States Department of Agriculture
Washington, D.C. 20250

By:

I. W. Kirk, Project Manager for ARS Laboratories:
Areawide Pest Management Research, College Station, Texas
Application Technology Research, Stoneville, Mississippi
Application Technology Research, Wooster, Ohio

1. *Description of any new or improved product or service that resulted from the Agreement.*

Air Tractor, Inc. changed the factory installed nozzles on all of their agricultural aircraft to one that produces less spray drift, based on USDA research.

CP Products, Inc. incorporated nozzle performance models in their World Wide Web home page that were developed in USDA research.

Report of Inventions:

USDA patented the aerial electrostatic spray system. Spectrum Electrostatic Sprayers, Inc. of San Antonio, Texas, licensed the patent and has a commercial prototype under evaluation.

Report of Sub-awards by USDA:

None

2. *Technical Report -- CRADA No. 58-3K95-4-237 between the USDA, USEPA, and the Spray Drift Task Force:*

The original Statement of Work for the CRADA and subsequent Amendments were outlined in a series of Tasks. The Tasks were primarily designed for the EPA to oversee, review, and concur in the SDTF mission to provide foundation for the regulatory framework under which SDTF member companies would provide EPA with spray drift data that would be used in registration of crop protection products. ARS, under the CRADA, committed to develop field trial programs independent of the SDTF, but that would be supportive of spray drift research needs. The CRADA provided a means to coordinate the programs and avoid undesirable duplication of efforts.

Task 1 - Review of Field Trial Protocols and Data

Application Parameters for Aerial Spray Nozzles (College Station)
Spray quality is a term adopted from the British Crop Protection Council (BCPC) in their classification of sprays for efficacy. ASAE, SDTF, EPA, and ARS have derived a similar classification of sprays for spray drift. ASAE is in process of documenting the classification under ASAE Draft Standard PM-41 X-572. It is possible, based on this standard, that some pesticide labels may specify that a given crop protection material can only be applied in a spray quality classified, for example, as "Medium" spray. That means that applicators will need to know the spray quality delivered by their spraying system for every nozzle, pressure, etc. combination they may need to use with their system. Several studies have been conducted to develop spray quality information on commonly used spray nozzles. Models were developed for predicting spray quality parameters for various operating conditions for the CP nozzle which is used on over 60 percent of aerial applications. There are several sources that applicators can reference for spray quality information -- technical literature, nozzle manufacturer's literature and WWW home pages, SDTF database and models, and aerial nozzle models. Extensive educational efforts are needed to communicate the meaning and utility of spray quality to applicators of crop protection materials.

1. Maynard, R. A. II, A. R. Womac, and I. W. Kirk. Nozzle classification factors for ground applications. Am. Soc. Agric. Eng. Paper No. 96-1074. 1996.
2. Kirk, I. W. Application parameters for CP nozzles. Am. Soc. Agric. Eng. Paper No. AA97-006. 1997.
3. Kirk, I. W. Spray quality from CP straight stream nozzles. Am. Soc. Agric. Eng. Paper No. AA98-002. 1998.
4. Kirk, I. W. Communicating spray quality nozzle by nozzle: what the applicator needs to know and where to get it. Proceedings of Spray Drift Task Force Spray Nozzle Workshop, March 1, 1999, Abstract.
5. Womac, A. R., R. A. Maynard, II, and I. W. Kirk, Reference spray measurements for nozzle classification. Submitted to Transactions of the ASAE.

2. Technical Report – CRADA No. 58-3K95-4-237 Between the USDA, USEPA, and the Spray Drift Task Force.

The original Statement of Work for the CRADA and subsequent Amendments were outlined in a series of Tasks. The Tasks were primarily designed for the EPA to provide review and advice to the SDTF mission to provide foundations for the regulatory framework under which SDTF member companies would provide EPA with a set of data that would be used in registration of crop protection products. Also, under the CRADA, commitment to develop field trial programs undertaken by the SDTF, but this would be a consortium. Further, drift research needs. The CRADA provided a forum to coordinate the programs and avoid unnecessary duplication of efforts.

Task 1 - Review of Field Trial Protocols and Data

Application Parameters for Aerial Spray Nozzles (I. W. Kirk, USDA-ARS)
Spray quality is a term adopted from the British Crop Protection Council (BCPC) for classification of sprays for efficacy. ASAE, SDTF, EPA, and ARS have devised a similar classification of sprays for spray drift. ASAE is in process of documenting the classification under ASAE Draft Standard S-572. It is possible, based on this standard, that some pesticide labels may specify that a given crop protection material can only be applied in a spray quality classified, for example, as "Medium" spray. That means that applicators will need to know the spray quality delivered by their spraying system for every nozzle, pressure, etc. combination they may need to use with their system. Several studies have been conducted to develop spray quality information on commonly used spray nozzles. Models were developed for predicting spray quality parameters for various operating conditions for the CP nozzle which is used on over 80 percent of aerial applications. There are several sources that applicators can consult for spray quality information — technical literature, nozzle manufacturer's literature and WWW home pages, SDTF database and models, and aerial nozzle models. Extensive educational efforts are needed to familiarize the meaning and utility of spray quality to applicators of crop protection materials.

1. Maynard, R. A. II, A. R. Womac, and I. W. Kirk. Nozzle classification, focusing on ground applications. Am. Soc. Agric. Eng. Paper No. 96-1074. 1996.
2. Kirk, I. W. Application parameters for CP nozzles. Am. Soc. Agric. Eng. Paper No. AA97-006. 1997.
3. Kirk, I. W. Spray quality from CP straight stream nozzles. Am. Soc. Agric. Eng. Paper No. AA98-002. 1998.
4. Kirk, I. W. Communicating spray quality nozzle by nozzle: what the applicator needs to know and where to get it. Proceedings of Spray Drift Task Force Spray Nozzle Workshop, March 1, 1999. Arkansas.
5. Womac, A. R., R. A. Maynard, II, and I. W. Kirk. Reference spray measurements for nozzle classification. Submitted to Transactions of the ASAE.

Aerial Electrostatic Spray System (College Station)

Following several years of research on aerial electrostatic sprays a commercial-ready prototype system was installed on a Cessna AgHusky. Recent research on aerial electrostatic systems was initially directed at improving spray deposition on the underside of leaves to improve control of whitefly. The system was evaluated in field-scale studies for two years in Arizona on whitefly control and for two years, applying ULV malathion and alternate pesticides for control of boll weevil in boll weevil eradication program simulations in the Brazos River Valley (TX). Results from these studies indicated that electrostatic applications at 1 gallon per acre (GPA) gave similar control as standard 5 GPA aerial application treatments with the same per-acre active ingredient (AI) rates. Half AI rates applied electrostatically in a 1 GPA spray mix had slightly lower efficacy than the full AI rates applied either electrostatically in 1 GPA or conventionally in 5 GPA. The aerial electrostatic system was used in a field study in 1998 that compared 0.05 lb AI/acre of fipronil applied in 1 GPA water-based spray mix with the same AI rate of fipronil in 12 oz/acre of once-refined cottonseed oil. The third treatment in this study was 12 oz/acre of ULV malathion. The electrostatic application of fipronil gave better control of boll weevil in laboratory bioassays with leaves from treated plots than 12 oz/acre of ULV malathion (55 percent compared to 33 percent mortality, respectively, three days after spray application). The ULV malathion treatment gave higher boll weevil mortality than the fipronil in oil. Studies conducted early in the development of this aerial electrostatic system indicated that the system could be useful in reducing the small droplet component of the spray spectrum that is more susceptible to spray drift.

1. Carlton, J. B., I. W. Kirk, and M. A. Latheef. Cotton pesticide deposition from aerial electrostatic charged sprays. Am. Soc. Agric. Eng. Paper AA95-007. 1995.
2. Latheef, M. A., J. B. Carlton, and I. W. Kirk. Electrostatically charged aerial sprays for control of sweetpotato whitefly in cotton: efficacy. Am. Soc. Agric. Eng. Paper AA95-008. 1995.
3. Carlton, J. B., L. F. Bouse, and I. W. Kirk. Electrostatic charging of aerial spray over cotton. Transactions of the ASAE 38(6):1641-1645, 1995.
4. Latheef, M. A., J. B. Carlton, and I. W. Kirk. Seasonal control of sweetpotato whiteflies in cotton using aerial electrostatic charged sprays. Proc. Beltwide Cotton Conf., 2:1035-1036, 1996.
5. Carlton, J. B., I. W. Kirk, and M. A. Latheef. Cotton pesticide deposition from aerial electrostatic charged sprays. Proc. Beltwide Cotton Conf., 2:1036-1040, 1996.
6. Carlton, J. B., I. W. Kirk, and M. A. Latheef. Aerial electrostatic charged sprays for control of sweet potato whitefly in cotton. *In* Silverleaf Whitefly: Supplement to the Five-Year National Research and Action Plan, ARS-1996-01:60, 1996.
7. Latheef, M. A., J. B. Carlton, and I. W. Kirk. Aerial electrostatic charged sprays for control of sweet potato whitefly in cotton. *In* Silverleaf Whitefly: Supplement to the Five-Year National Research and Action Plan, ARS-1996-01:76, 1996.

[illegible]

[illegible] Cotton pesticide [illegible]

[illegible] Action Plan [illegible]

Influence of Crop Canopy on Spray Deposition and Drift (College Station)
The nature and extent of plant canopies influence (1) spray deposition or interception on and within the canopy and (2) the amount of spray that is not deposited and subsequently leaves the intended target area as spray drift. Studies were conducted to characterize crop canopies and relate canopy characters to spray deposits. Studies were conducted to relate these factors to spray drift, but weather conditions were not conducive to spray drift and subsequent demands for other work precluded repeating the effort.

1. Kirk, I. W., L. F. Bouse, J. B. Carlton, E. Franz, M. A. Latheef, J. E. Wright, and D. A. Wolfenbarger. Within-canopy spray distribution from fixed-wing aircraft. Transactions of the ASAE 37(3):745-752, 1994.
2. Bouse, L. F., J. B. Carlton, I. W. Kirk, and T. J. Hirsch, Jr. Nozzle selection for optimizing depositon and minimizing drift for the AT-502 Air Tractor. Transactions of the ASAE 37(6):1725-1731, 1994.
3. Franz, E., J. B. Carlton, L. F. Bouse, and I. W. Kirk. Within-canopy airflows and spray movement for fixed-wing aircraft. Transactions of the ASAE 38(2):389-394, 1995.
4. Franz, E., L. F. Bouse, J. B. Carlton, I. W. Kirk, and M. A. Latheef. Aerial spray deposit relations with plant canopy and weather parameters. Transactions of the ASAE 41(4):959-966, 1998.

Managing Spray Drift from Agricultural Aircraft (College Station)
Several field studies were conducted to characterize spray drift from both fixed-wing and rotary-wing spray aircraft. Additional field studies were conducted to demonstrate various approaches to mitigating spray drift. AGDISP and AgDRIFT have facilitated simulation studies to demonstrate the effectiveness of single and multiple aerial drift mitigation practices that can be adapted to individual operator's aircraft and application conditions. One of these studies coupled with extension educational efforts prompted a major agricultural aircraft manufacturer to change factory installed spray nozzles to a model that was less prone to cause spray drift. A retractable boom system was developed and tested for airworthiness and spray performance; study results show improved spray deposition characteristics and reduced spray drift.

1. Kirk, I. W., R. D. Fears, and L. F. Bouse. Spray drift from straight-stream nozzles on a helicopter. Am. Soc. Agric. Eng. Paper AA94-002. 1994.
2. Bouse, L. F., J. B. Carlton, I. W. Kirk, and T. J. Hirsch, Jr. Nozzle selection for optimizing depositon and minimizing drift for the AT-502 Air Tractor. Transactions of the ASAE 37(6):1725-1731, 1994.
3. Bouse, L. F., J. B. Carlton, E. Franz, and I. W. Kirk. Aircraft spray nozzles for minimizing spray drift and optimizing spray deposition on cotton. *In* Silverleaf Whitefly: Supplement to the Five-Year National Research and Action Plan, ARS-125:82, 1994.
4. Bouse, L. F., Carlton, J. B., Franz, E., Kirk, I. W., and Latheef, M. A. Improved delivery systems for increased efficacy and safety in aerial spray applications. Second National IPM Symposium/Workshop, Las Vegas, Nevada, Apr. 1994.
5. Kirk, I. W. and H. H. Tom, Precision GPS flow control for aerial spray applications. Am. Soc. Agric. Eng. Paper No. AA96-009. 1996.

6. Kirk, I. W. and H. H. Tom, Precision GPS flow control for aerial spray applications. *in* Precision Agriculture, Proc. of the 3rd Int. Conf., 815-817, ASA/CSSA/SSSA, 1996. Kirk, I. W. Managing spray drift from aerial fixed-wing applications. Proc. North American Conference on Pesticide Spray Drift Management. pp. 88-100, 1998.
6. Hoffmann, W. C., and H. H. Tom. Effects of lowering spray boom in flight on swath width and drift. Am. Soc. Agric. Eng. Paper No. AA98-004. 1998.
7. Kirk, I. W., S. J. Harp, and W. H. Hendrix. Advances in coverage and application technology. Proceedings of Dow AgroSciences Tracer Research Exchange Meeting. February 13, 1999.

Spray Drift Sampling Methodology (Stoneville)
A key element in solving problems of spray drift is the ability to accurately sample spray drift. Samplers are needed to quantify the various phase components of spray drift to adequately evaluate drift potential of various pesticide application technologies. Several different samplers were evaluated to verify their performance in quantification of pesticide drift leaving the targeted area in liquid, solid, and gas phases. A rotary disk impactor (RDI) phase partitioning sampler efficiently quantified pesticide drift according to the amount of liquid, solid, and gas that is leaving the targeted area. Little difference in residue collection between high volume air samplers, rotating rod samplers, or vertical string samplers was observed. A rotary disk impactor failed to collect any of the droplets from a drifting spray cloud.

1. Womac, A. R., M. K. Amin, T. C. Mueller, J. E. Mulrooney, Q. D. Bui, and D. Goli. 1994. Sampling Airborne Pesticide Residues by Phase Partition. ASAE Paper #941504 Amer. Soc. Ag. Eng. St. Joseph, MN.
2. Womac, A. R., M. K. Amin, T. C. Mueller, and J. E. Mulrooney. 1995. Air Sampling of Aerosol and Gaseous Pesticides. ASTM Symposium on Sampling Environmental Media. Amer. Soc. Test. Mater. Philadelphia, PA.
3. Bui, Q. D., A. R. Womac, K. D. Howard, J. E. Mulrooney, and M. K. Amin. 1998. Evaluation of Samplers for Spray Drift. Trans. ASAE. 41:37-41.

Spray Drift from Air-Assist Ground Sprayers (Stoneville)
The use of air-assisted boom sprayers for the application of agricultural pesticides has increased over the last five years. This increase in use has been driven by concerns related to off-target drift and the need for increased deposition on the leaf under-side for the control of insects and plant diseases. Due to this increased usage, a cooperative research effort to evaluate air-assisted boom sprayers was developed. Five standardized studies were developed for the evaluation of air-assisted boom sprayers. These studies consist of measurement of off-target particle drift, weed and insect control efficacy, canopy deposition and penetration on the upper- and under-side of the leaf, and deposition of a cotton defoliate. Preliminary results indicate that there is a greater potential for off-target particle drift when lower rates of carrier volume and the higher air speeds are used in a bare ground situation. In a canopy situation, air-assisted boom sprayers do achieve greater coverage and efficacy than the conventional over-the-top sprayer at the same rate of carrier volume. Efficacy is also dependent upon the rate of

carrier volume, the chemical rate and the spray target. The results also showed that all the sprayers deposited more active ingredient on the underside of the leaves at both the top and middle locations than the hydraulic over-the-top sprayer. However, only two of the sprayers deposited more active ingredient on the upperside of the leaves at the top and middle canopy locations. The tests indicated that significant differences exist in the amount and type of drift created by different air-assist and air-shear sprayers.

1. Howard, K. D., J. E. Mulrooney, L. D. Gaultney, and T. F. Helmer. 1995. Testing Protocol for the Evaluation of Air-Assisted Boom Sprayers. ASAE Paper #95116. Amer. Soc. Ag. Eng. St. Joseph, MN.
2. Gaultney, L. D., K. D. Howard, and J. E. Mulrooney. 1996. Off-Target Drift with Air-Assisted Agricultural Sprayers. In , Pesticide Formulations and Application Systems: 16th Volume, ASTM STP 1312, H. M. Collins, G. R. Goss, and M. Hopkins, eds., Amer. Soc. Test. Mater.
3. Howard, K. D., J. E. Mulrooney, L. D. Gaultney. 1994. Penetration and Deposition of Air-Assisted Sprayers. ASAE Paper #941024. Amer. Soc. Ag. Eng. St. Joseph, MN.

Aircraft Speed and Spray Drift (Stoneville)

The downwind spray drift resulting from aerial application was investigated using high-volume air samplers in a cotton field. A turbine-powered, monoplane was operated at 218, 241, and 265 km/h over a 700-m flight line oriented 23.6° from a 610-m sampler line. Results using cinnamyl alcohol tracer, quantified by gas chromatography, indicated that concentrations collected from air sampler filters were not significantly different (P=0.05) for all velocity treatments at individual stations up to a distance of 67 m from the flight line center. Drift from the 218 km/h treatment was significantly (P=0.05) greater than that from the 241 and 265 km/h treatments at individual stations from 79 to 201 m. Wind velocity ranged from 1.65 to 3.34 m/s. Spray droplet volume median diameters were 247, 218, and 189 : m for the velocities of 218, 241, and 265 km/h, respectively. Volume of spray in small droplets less than 125 : m increased from 3.53 to 16.7% as velocity increased. The strengths of wingtip aerodynamic vortex of the 241 and 265 km/h treatments, compared to that for 218 km/h, decreased by approximately 10 and 22%, respectively, thereby offsetting the potential drift corresponding to a decrease in droplet size of 12 and 23%.

1. Womac, A. R., J. E. Mulrooney, and L F. Bouse. 1993. Spray Drift from High-Velocity Aircraft. Trans. ASAE. 36: 341-347.

Air Deflectors and Spray Drift (Stoneville)

Air deflectors (Chimavir Air Services, Ltd., Israel) were installed on an agricultural aircraft and tests were run to investigate: (1) the alteration in downwind residue results (drift) due to release height, (2) the influence on droplet sizes conducted with a laser drop size analyzer in a wind tunnel, and (3) the changes in air flow near the spray boom as observed from wind tunnel tests. A turbine-powered monoplane with air deflectors was evaluated for spray drift losses and deposit characteristics in a cotton field. Air-burden residue from application heights of 3.0, 4.6, and 6.1 m were investigated using high-

volume air samplers along a 610-m sampler line oriented at 23.6° from a 700-m flightline. Spray deposit was measured (concurrent with the downwind airborne drift sampling) from collection of residue on Mylar plastic sheets spaced at 6.1-m intervals from the first air sampler to beyond the flightline. Gas chromatographic analysis was used to measure the concentration of cinnamyl alcohol tracer. Results from air samplers indicated that the 3.0-m release height had significantly (P=0.05) less airborne drift (2.19 ppm) than the 4.6 m height (9.52 ppm) and 6.1 m height (11.37 ppm). No significant differences (P=0.05) in fallout deposit levels were detected, although the 4.6 m height tended to have a higher level of deposit (6.06 ppm) than the 3.0 m height (4.29 ppm) and the 6.1 m height (4.62 ppm). Spray droplet sizes produced in a wind tunnel with and without a deflector were examined for a custom-sized RF 25° fan nozzle (3.06 L/min at 276 kPa, Delavan-Delta, Inc., Lexington, Tenn.) and a D6-46 disk and core nozzle (Spraying Systems Co., Wheaton, Ill.). Both nozzles were oriented 45° down and back with airstream velocities of 60 and 75 m/s. Water-soluble formulations were examined and included (1) cinnamyl alcohol, (2) bifenthrin, and (3) water. Overall mean droplet sizes (Malvern) with the deflector were 235 : m, whereas without the deflector they were 182 : m. The downwash of air around the deflector was quantified in terms of mean, steady-state air velocity and direction. Measurement points were selected on a two-dimensional grid that ran longitudinally with the axis of the wind tunnel. Air was deflected to an angle of 50° from horizontal. A 54 m/s air flow was decelerated to 40 m/s behind the deflector.

1. Womac, A. R., J. E. Mulrooney, B. W. Young, and P. R. Alexander. 1994. Air Deflector Effects on Aerial Sprays. Trans. ASAE. 37: 725-733.

Spray Drift from Aerial Straight Stream CP Nozzles (Stoneville)

Drift of malathion spray from the target area was evaluated for the three deflection angles available on the Straight Stream CP nozzle. Zero deflection (straight stream), 5 degree and 30 degree deflections were evaluated in a randomized complete block experiment with five replications. An application rate of 225 g/ha (0.2 lbs/acre) malathion was sprayed in 18.7 l/ha (2 gal/acre) of water on each of the two passes made for each of the 15 runs made during the experiment. The spray passes for each run were made in opposite directions on the same flight line. Weather data, which included wind speed and direction, temperature, and humidity, was monitored at three levels and recorded at 1-minute intervals adjacent to the test site. Video records of each pass were used to establish the height of the spray boom. Spray Cards and fallout sheets were used to evaluate spray deposits in the swath and downwind from the swath for a distance of 256 meters. High volume air samplers were also used to compare spray collected in the swath and 32 meters downwind from the swath. Quantities of malathion collected on the fallout sheets and the air sampler filters will be presented for relative comparisons of off-target movement of sprays as affected by nozzle deflection angle. Spot number, size and area from the spray cards will be presented to describe the relative coverage of the spray.

1. Smith, L. A., J. E. Mulrooney, and S. J. Thompson. Drift Reduction from the Straight Stream CP Nozzle. Not published.

[illegible] sample [illegible] mm [illegible]

[illegible] spray deposit [illegible] from [illegible] also from collection [illegible] the first [illegible] to measure the [illegible] in the 5.0 [illegible]

[illegible] have a higher [illegible] the height of [illegible] Spray deposit [illegible] the deflection was [illegible]

a. Deflection

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[illegible] with [illegible]

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[illegible]

Effects of Aerial Spraying [illegible]

[illegible] the [illegible] 2 mm [illegible] deflections [illegible] evaluated [illegible] same [illegible] applications. An analysis of the [illegible] (2 gallons of water [illegible]) made during the experiment [illegible] on the same flight line [illegible] temperature and humidity [illegible] adjacent to the test site [illegible] the height of the spray [illegible] high volume air samplers were [illegible] from the [illegible] air sampling filters [illegible] was affected by [illegible] it will be [illegible]

J. E. [illegible] from the [illegible]

Spray Drift from Aerial and Ground Applications of ULV Malathion (Stoneville)
Spray drift from ultra-low volume applications of malathion ULV both by air and ground have been investigated. This research was conducted in support of boll weevil eradication and was used to assess the impact of malathion application and drift on the catfish industry in Mississippi. (Not published)

Drift Experiments in Orchards (Wooster)
Several studies have been conducted on drift from spraying orchards with air-blast and air-curtain sprayers. The protocol for these experiments has been to spray the outside (downwind) row of trees using the drive-row between the last two rows of trees, and spraying outward (with the wind) only. Spray deposits on ground collectors and airborne spray deposits on passive collectors (earlier string and plastic tape, now nylon screen) and on filter paper in a high volume air sampler have been measured. Ground collectors have been located from the edge of the orchard to 256 m downwind, in a logarithmic spacing. High volume samplers have been located from 8 m to 256 m downwind and the nylon screens are mounted from 1 to 10 m elevations at 1-m spacing. The vertical sampling towers are 8 m downwind. Three parallel sample lines are used. Spiked samples are used to account for background effects of experimental field conditions on samples collected on plastic-tape substrates used for ground-level assessment of spray drift. Micro-meteorological parameters measured include wind velocity at two locations downwind from the sprayed orchard, at 5.9 and 10-m elevations. Air temperature at 2, 2.5 and 10-m elevations, relative humidity, atmospheric pressure and solar radiation at approximately 2-m elevation are measured. In addition air speed is measured at 2.5 and 10 m for Richardson Number calculation. Two fluorescent tracers are used when comparing spray application systems. After each spray pass with both sprayers, the collectors are marked and stored and new collectors exposed. A principal finding is that a prototype air-curtain sprayer equipped with three cross-flow fans can significantly reduce airborne spray drift compared with a conventional, axial-fan orchard air sprayer. Under the conditions imposed in experiments to date, ground deposits were about the same for both systems.

1. Fox, RD, RD Braze, C.R. Krause, R.C. Deerskin, S.A. Svensson and H.E. Ozkan. 1997. Effect of wind velocity on downwind deposits from spraying orchards. Proceedings of 5th International Workshop on Spraying Techniques in Fruit Growing. June 16-19, 1997, Radziejowice, Poland. Acta Horticulturae
2. Fox, R.D., R.C. Derksen, R.D. Brazee and H. E. Ozkan 1998. Airblast/Air-Assisted Application Equipment and Drift. Proceedings of North American Conference on Pesticide Spray Drift Management, Portland, ME, 108-129.
3. Fox, R.D., R.C. Derksen, R.D. Brazee and H.E. Ozkan. 1998. Drift measurement: methods and techniques. Conference on Measurement and Management of Agrochemical Spray Quality. Taiwan Agricultural Research Institute, Taichung, Taiwan. Dec 17-18, 1998, 139-168.
4. Ozkan, H.E., R.D. Fox, R.C. Derksen and R.D. Brazee. 1998. Methods of drift control. Conference on Measurement and Management of Agrochemical Spray Quality. Taiwan Agricultural Research Institute, Taichung, Taiwan. Dec 17-18, 1998, 169-190.

[illegible]

and Engineering [illegible] American Conference [illegible]

[illegible] Portland, OR [illegible]

[illegible]

5. Salyani, M. and R.D. Fox. 1999. Performance of oil- and water-sensitive papers in spray coverage evaluation. Transactions of ASAE 42(1):37-43.

Nursery Crop Experiments (Wooster)

A series of experiments has been conducted in commercial nurseries in Lake County, Ohio. These experiments have focused on spray coverage with the trees (honey locust, Canadian hemlock, and red maples) using high-clearance, axial-flow and cross-flow fan sprayers. Some assessments of downwind deposits were also made. Studies in 1998 evaluated deposits on the second and third row upwind using the two types of air-carrier sprayer. The cross-flow sprayer jet was able to penetrate counter flowing wind and reach target foliage better than the axial-flow jet.

1. Derksen, R.C., C.R. Krause, R.D. Fox and R.D. Brazee. 1998. Near-row fate of air-curtain and orchard sprayer nursery crop applications. ASAE Paper No. 98-1007.
2. Derksen, R.C., C.R. Krause, R.D. Fox and R.D. Brazee. 1999. The effect of application variables on the effectiveness of nursery stock sprays. ASAE Paper No. 991029. (Mimeo handout)

Drift Reduction with Boom Sprayers (Wooster)

Several studies were conducted related to controlling drift with boom sprayers. Wind tunnel studies were conducted that compared the effectiveness of several shield configurations to control downwind deposits. Similar studies in a wind tunnel evaluated the effectiveness of 'drift reduction' and 'air induction' nozzles to reduce downwind spray deposits. A double-foil shield was found most effective of those examined for drift reduction. The drift reduction nozzles were found to deliver fewer small spray droplets, helping to mitigate drift.

1. Bayat, A., H.E. Ozkan, R.C. Derksen and R.D. Fox. 1999. Droplet spectrum and drift potential of Turbo Teejet and air induction nozzles. Proceedings of 7th International Congress on Mechanization and Energy in Agriculture,ICAME99, Adana, Turkey. Pp. 220-225.
2. Derksen, R.C., H.E. Ozkan, R.D. Brazee, H. Zhu and R.D. Fox. 1999. Effectiveness of TurboDrop nozzle in drift reduction. Submitted to ASAE Transactions
3. Ozkan, H.E., A. Miralles, C. Sinfort, H. Zhu and R.D. Fox. 1997. Shields to reduce spray drift. *J. Agricultural Engineering Research* 67:311-322.
4. Tsay, J.R., H.E. Ozkan, R.D. Brazee, R.D. Fox and R.C. Derksen. 1998 Evaluation of Pneumatic Shielded Spraying System Using Simulation. ASAE Paper No. 98-1009.

Orchard Edge Effect Experiment (Wooster)
An experiment on edge effect spraying was undertaken in late 1998. In this experiment the sprayer air jet was directed into the last downwind row from the outside on one pass, while on the next pass, the sprayer air jet was directed through the tree in the downwind direction. This experiment was designed to measure the reduction in drift amount to be attained by spraying the outside, downwind row only into the wind, and not for both sides, as is the normal practice. While our results were not conclusive, it seemed that the type of sprayer jet used was critical to the amount of drift reduction. An axial-fan sprayer and a cross-flow fan sprayer were used in these experiments. The cross-flow fan sprayer appeared to penetrate the wind above the trees better than the axial-fan sprayer, and thus, less drift was deposited downwind when the cross-flow fan sprayer was used. Analysis of results is incomplete and therefore not published.

Review of SDTF Drift Data (College Station, Stoneville, and Wooster)
ARS researchers reviewed data obtained by the SDTF and presented to USEPA. Reviews included drift data, droplet size, physical property, and collection efficiency measurements. A preliminary review of the results of orchard drift experiments was made at a meeting in the Washington D.C. area in June 1994. EPA called this review because downwind ground spray deposits reported by the SDTF were less than values being used by the EPA. Most reviewers at this session felt that the SDTF values were similar to most recent work on spray drift deposits.

SDTF data on drift from aerial spraying was reviewed in a meeting between the SDTF, ARS and several other outside reviewers in September 1997. ARS researchers were asked to review the drift measurements, and associated weather data, and deposits on 'spiked' samples used to verify field exposure with known deposits. Also reviewed was data on collection efficiency of the collectors used in the studies, actually some collector material was selected as a result of these studies. Reviews in this session included droplet spectra produced by all nozzles used in the field experiments and other nozzles at different spray conditions and when spraying several spray liquid formulations. The SDTF also demonstrated the aerial spray drift model that will be used by EPA to predict ground deposits and required buffer zone widths when spraying with aircraft.

A second conference to review SDTF data was held in December 1998. At the meeting, also before USEPA and including several other outside experts, ARS scientists reviewed downwind deposits from spraying with boom sprayers, orchards with air-blast sprayers, and chemigation applications. Droplet size spectra measurements and field verification samples were also included in this review.

Task 2 - Initial Model Testing and Evaluation

SDTF and USEPA selected AGDISP as the basis for the aerial drift module.

Task 3 - Minor Model Refinement and Final Testing

Continuum Dynamics, Inc. contracted for this task. AGDISP was streamlined and algorithms modified to better account for evaporation of small droplets in a low velocity wind field. The updated model is referred to as AgDRIFT.

Task 4 - Interface Development

Continuum Dynamics, Inc. contracted for this task. A Windows interface was developed for AgDRIFT. The model was structured with a three-tier interface with Tier I set for a series of standard application scenarios. Tier II allows for additional flexibility in operator input. Tier III provides complete operator input to AGDISP under the AgDRIFT interface. AgDRIFT® 1.05 is being distributed on letterhead request to SDTF Modeling Committee Chairman.

Task 5 - Post Processor Development

Continuum Dynamics, Inc., SDTF, and USEPA are continuing this effort based on industry and regulatory data reporting needs. AgDRIFT® 2.0 is scheduled for posting on USEPA's www model site in the fourth quarter of 1999.

Task 6 - Model of Dropsize Distribution as a Function of Formulation

USEPA has developed an empirical model called DropKick®. DropKick® II is also scheduled for posting on USEPA's www model site in the fourth quarter of 1999.

ARS has provided the CP nozzle models, which may be used as an alternative to DropKick® II for the 65 percent of aerial applications, made with CP nozzles.

ARS has provided data to ASAE in support of the standard for classification of spray nozzles based on spray drift propensity.

Additional Tasks were developed in Amendment 1 and Amendment 2 to the CRADA. USDA did not acknowledge these Amendments with signature and/or notification to CO-ADODR's.

3. Disclosure of inventions conceived or reduced to practice under the Agreement

P.C. 0248.96 A TECHNIQUE TO REDUCE CHEMICAL USAGE AND CONCOMITANT DRIFT FROM AERIAL SPRAYS was filed and a patent was subsequently issued. Spectrum Electrostatic Sprayers, Inc. was granted an exclusive license. Spectrum contracted with Chiquita Brands, Inc. for a commercial season-long trial with the system on bananas in 1999. Spectrum is also negotiating with Dole for the system. An applicator in Argentina has contracted for a system. There have been numerous inquiries but we are not aware of any sales in the US.